Embedded Systems
Remote Monitoring
Production Recorders

SingleChips Inc.
64 Springfield Street
Welland, Ontario
L3B 5L9

Tuesday, February 15, 2005

Proposed Underwater Pipeline Locator

Previous efforts to locate pipe buried 20 or 30 feet below lake bottom have been unsuccessful. Although the technology to accomplish similar tasks already exists in some form or another, it does not work at the bottom of Lake Erie for many reasons, some of which might be that the pipe is bare (uncoated), the environment is not friendly to off-the-shelf electronics, etc.

Through past work, we have identified a few key areas that can be improved in order to maximize detection distance, and custom equipment has been built for the purpose. Although we are not reinventing the wheel, testing will have to be done in actual lake-bottom conditions, because the environment is impossible to duplicate on land. All new and old methods listed below have the effect of increasing signal detection distance. These are:

1. **Very precise frequency control for very narrow detection bandwidth.** This is accomplished by using the PDL as a controller and a DDS (Direct Digital Synthesizer) chip. The result is a "dial a frequency" setup, with a frequency step of 0.04 Hz.
2. **Double or triple the transmitter power output.** Commercial pipe locators are usually available with a power output of a few Watts, some go up to 50 or 100 Watts. We intend to have the capability of applying up to 500 Watts into the pipeline.
3. **Match the source and load impedance on the transmitter side.** On land pipe locators almost never go through the trouble of load matching, probably because they don't have to. At lake bottom, we must try to do this so that power can be transferred as efficiently as possible.
4. **Increase the ground rod to pipeline separation.** The larger the distance between the pipeline and ground rod, the better. How far? we should be able to locate the ground rod up to 1000 feet away from the pipeline.
5. **Determine the best way to couple the signal to the pipeline.** It may be to our advantage to implement an inductive coupling rather than direct coupling. See Figure 3.
6. **Dramatically increase reception sensitivity by using DSP (Digital Signal Processing).** This capability may well determine success or failure as we will be able to track the signal as we move away from the source. With this technique, audio from the receiver is processed by a computer running DSP software and a realtime graphic is produced where received signals are visually presented. Due to the random nature of noise, it is easy to spot a man-made signal, even if its power is less than the noise.
7. **Other miscellaneous improvements, reception antenna, etc.** Because the bare pipe is always in contact with the ground, the pipeline system is electrically an extremely low impedance system. This has been interpreted in the past as a "short", rendering further work impossible. The proposed work will prove the impedance is very low, in the order of a tenth of an ohm and even lower. Both transmit and receive systems must be low impedance systems. An example of this is the single turn, amplified loop antenna.

Standard Transmitter

The diagram depicts what many pipe locators do on land. There is no provision for impedance matching, as the pipeline is coated and as such carries current easily.

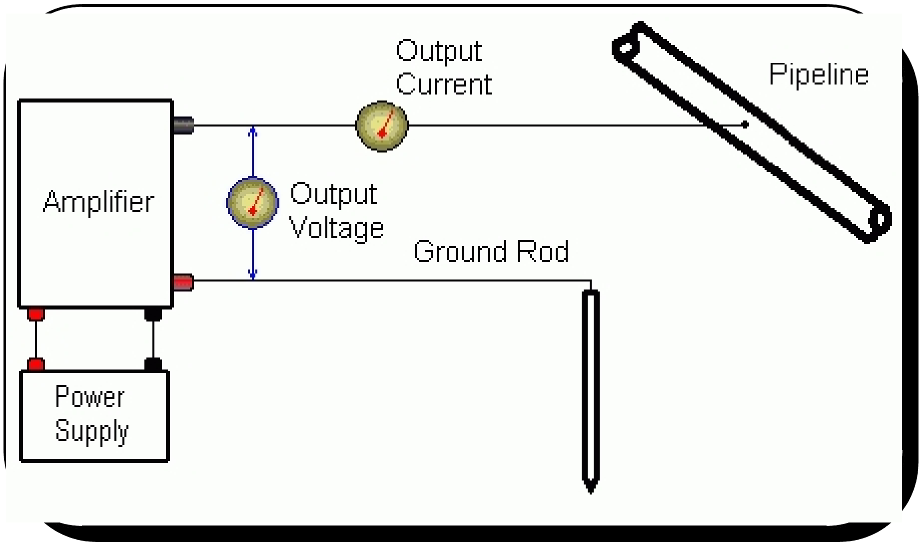


Figure 1. Typical Pipe Locator Transmitter

Improved Transmitter

Improved system incorporates a transformer with appropriate turns ratio to match source and load impedances.

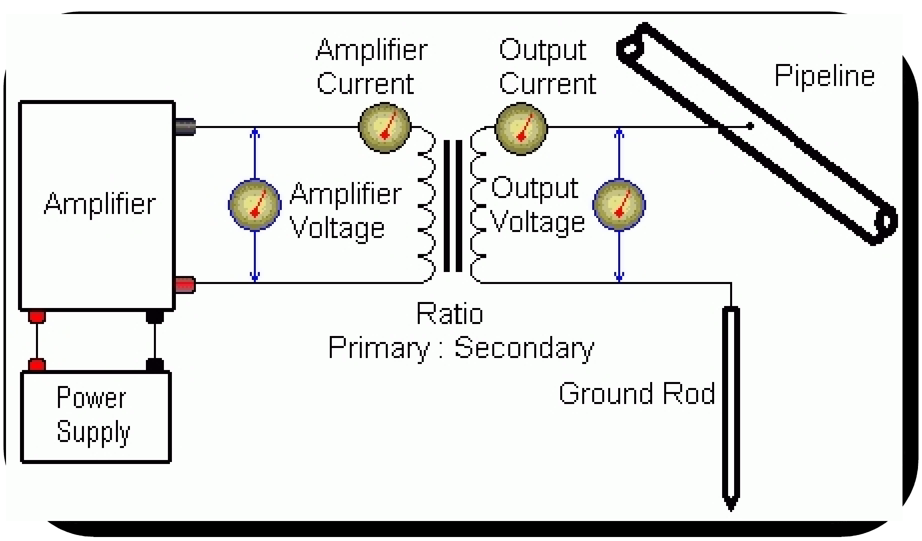


Figure 2. Output Matching Transformer Improves Power Transfer

Alternate Coupling Method

It may be more effective to couple the signal to the pipeline by wrapping a few turns of wire around the pipeline and matching to the amplifier through a transformer.

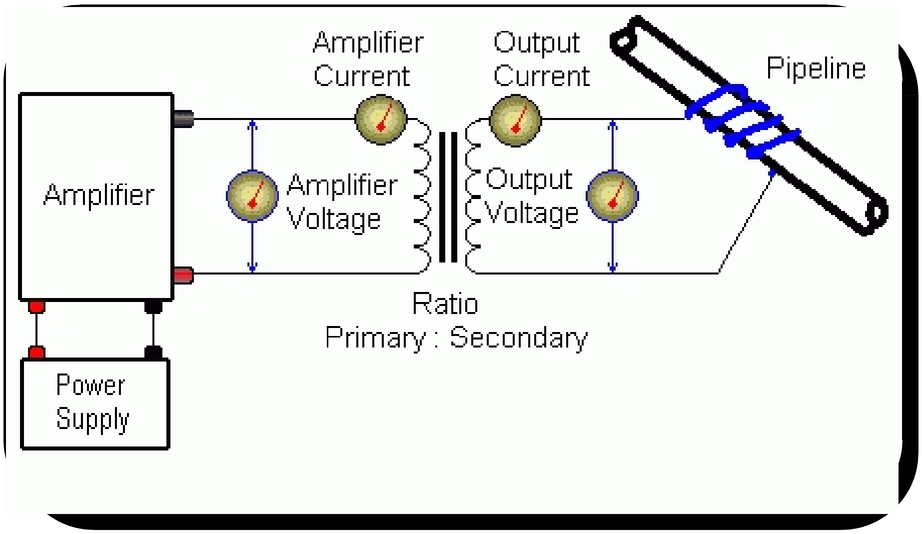


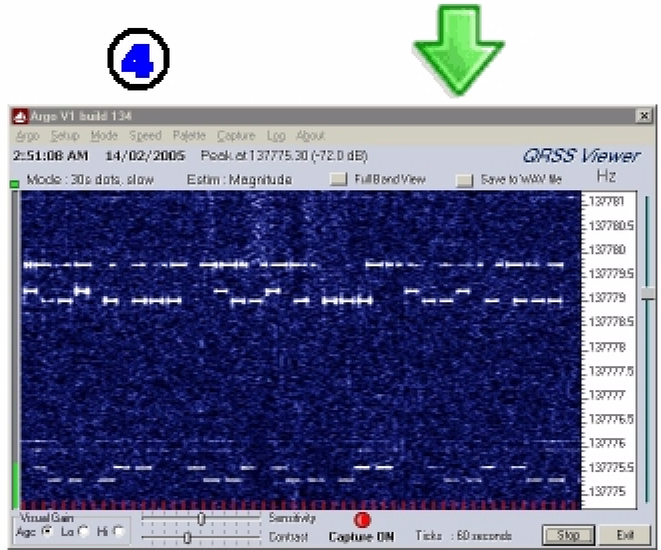
Figure 3. Optional Inductive Coupling

Reception

The reception scheme depicted below is capable of detecting extremely weak signals thanks to the wide availability of DSP software for the computer sound card. A directional antenna is connected to a commercial radio the audio output of which feeds the sound card in a computer. After some processing, the computer updates a scrolling bitmap in near realtime. Relative signal strength is indicated by the brightness of the lines on the screen

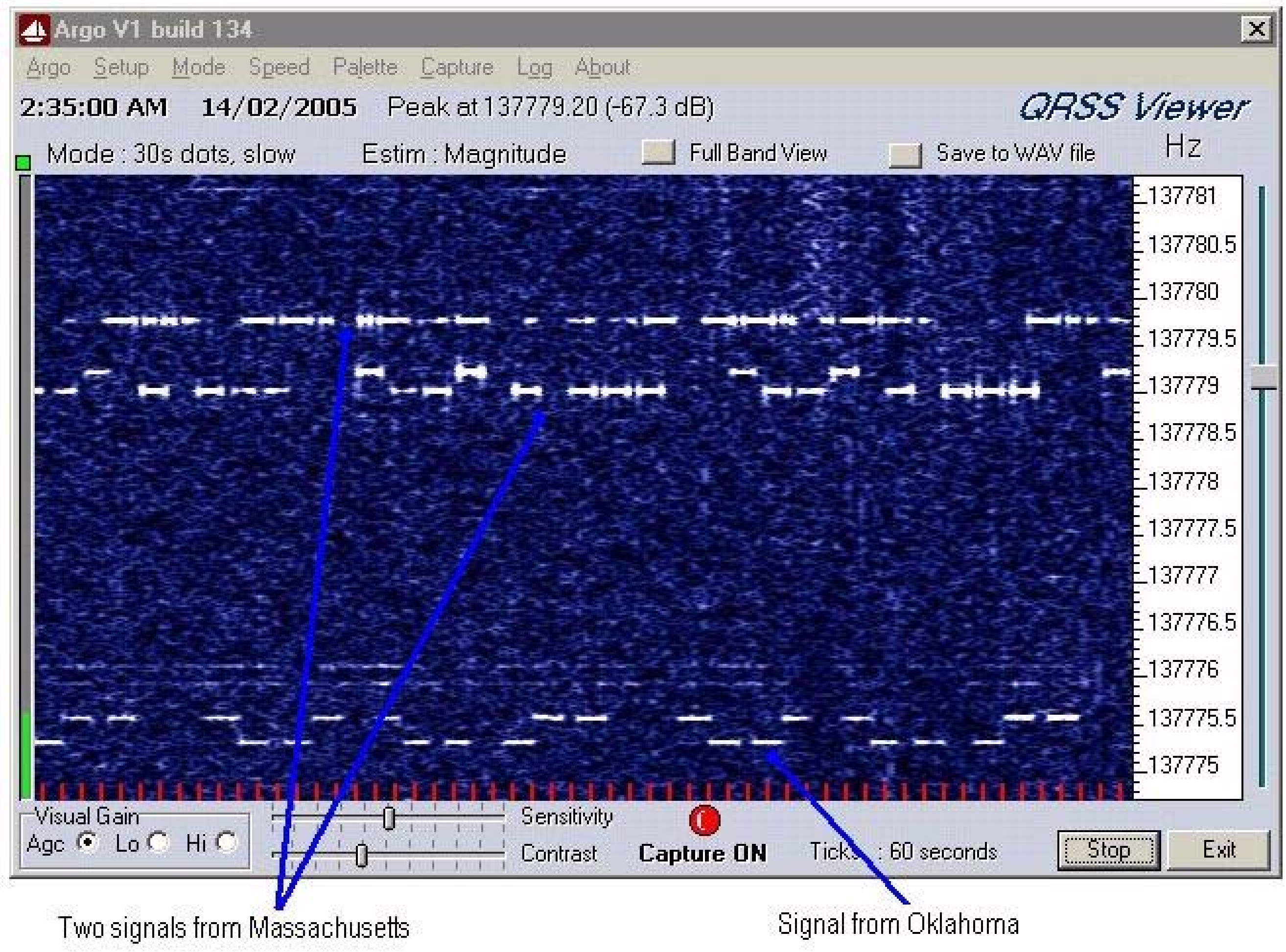
Receiving Setup

1. Amplified Magnetic Loop Antenna. This antenna is a single turn, shielded, and amplified loop. Has typical loop characteristics including being very directional.
2. Communications Receiver. ICOM R-75, a great radio for low frequency listening.
3 . Laptop running DSP (Digital Signal Processing) software on inputs into the sound card.
4. Digital display of signals, even if the signals are extremely weak (at or below noise level).

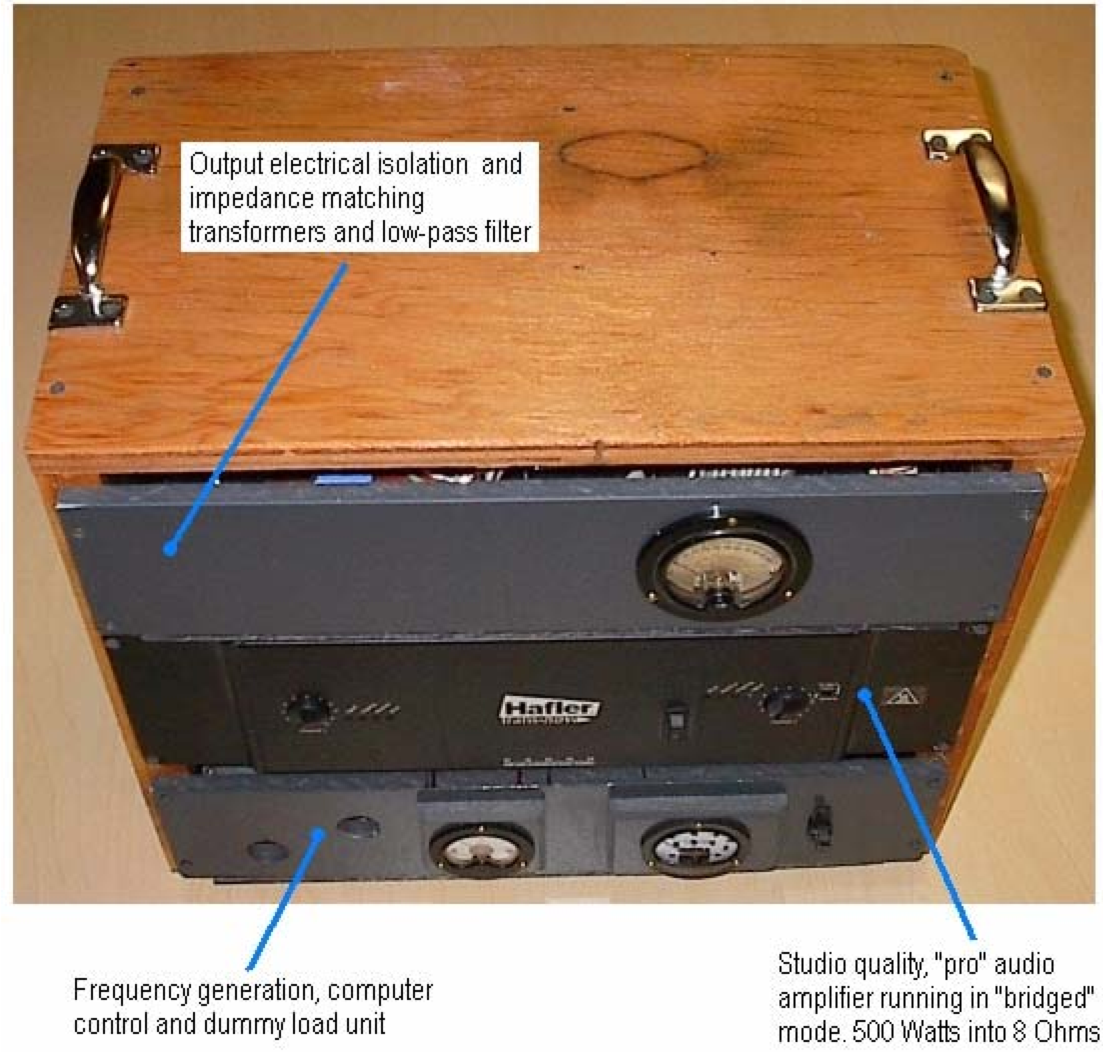


Example DSP Reception

The example screen below was recorded in Welland the early morning hours on February 14th, using two ground rods spaced 30 meters apart as a receive antenna. Note the entire screen is only 6 Hertz wide, with the top two signals from Massachusetts being only half a Hertz apart. If we were to record a standard AM radio station at the same resolution, the screen would have to be 1000 times taller.



Equipment - Transmitter

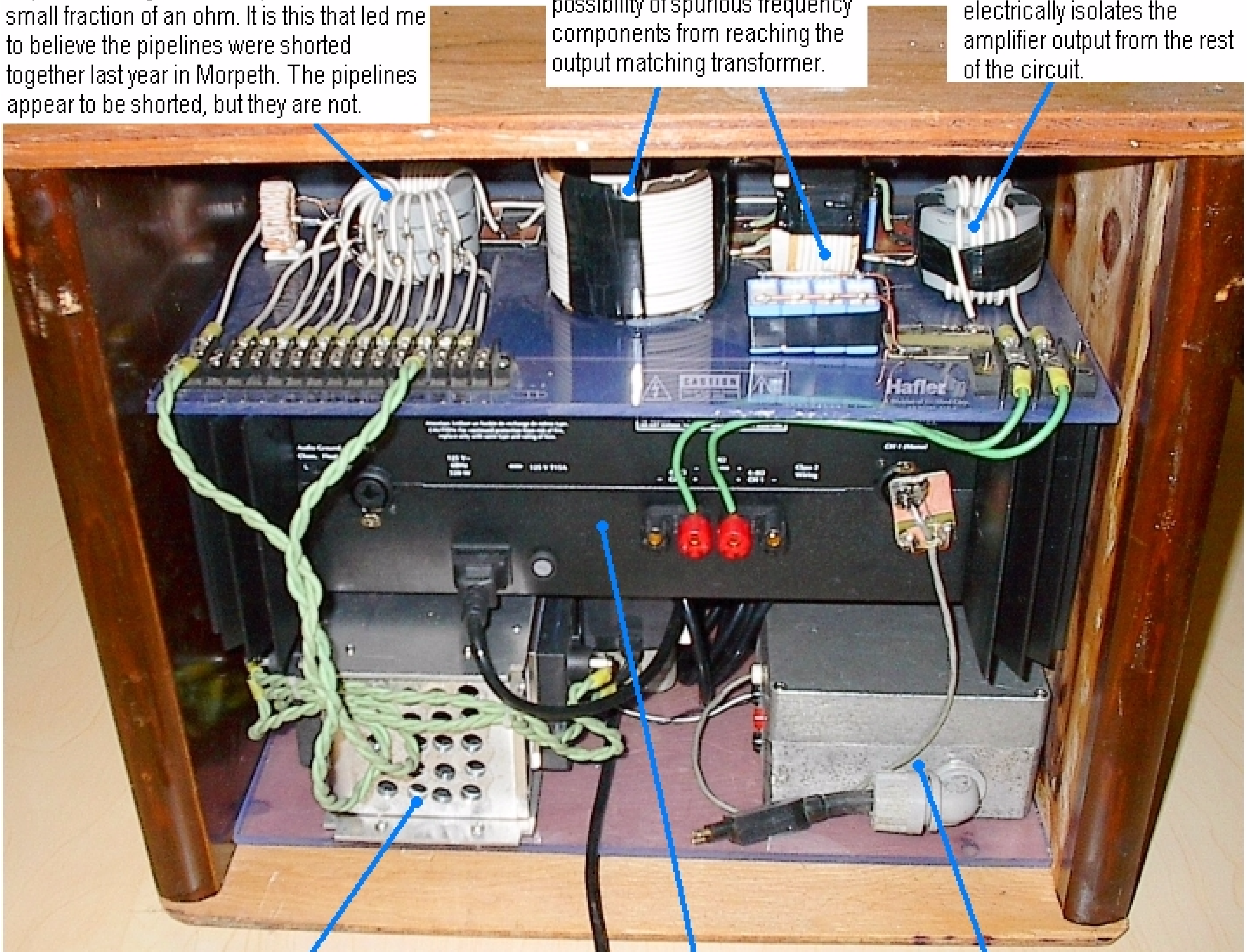


Transmitter Components

3-ring toroid output matching transformer. Capable of matching impedance from about 14 ohms down to a 0.1 ohm. The pipeline impedance to ground is expected to be a small fraction of an ohm. It is this that led me to believe the pipelines were shorted together last year in Morpeth. The pipelines appear to be shorted, but they are not.

Low pass filter components. This section of the circuit prevents the possibility of spurious frequency components from reaching the output matching transformer.

3-ring toroid isolation transformer, does nothing but electrically isolates the amplifier output from the rest of the circuit.



Forced air dummy load used for testing. The two black things attached to the sides are 25 ohm, 1000 Watt resistors, connected in parallel. In normal use, the two green wires from the matching transformer above would connect to the pipeline.

Hafler P4000 audio amplifier running in bridged (mono) mode, produces up to 550 Watts into 8 ohms. The pair of green wires at the red terminals feed the isolation transformer above.

Standard PDL modified to become a computer controlled frequency generator. The gray wire feeds this frequency signal into the audio amplifier input.

Equipment - Radio, Amplified Antenna

Equipment - Impedance Bridge

Digital Impedance Bridge - Standard amateur radio equipment heavily modified to allow measurement of pipeline impedance at very low frequencies. This will be used (for the first time) to actually measure the pipeline impedance and response to frequency.